I. C. 6710 May, 1933

DEPARTMENT OF COMMERCE

UNITED STATES BUREAU OF MINES
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EXPLOSIONS IN PENNSYLVANIA COAL MINES, 1870-1932

BY

J. J. FORBES AND H. B. HUMPHREY

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EXPLOSIONS IN PENNSYLVANIA COAL MINES, 1870-1932[1]

By J. J. Forbes[2] and H. B. Humphrey[3]

PURPOSE OF THIS REPORT

In accident prevention, a study of statistical data is necessary to determine primary causes of accidents to devise means to eliminate causes at the original sources. Explosions in coal mines of the United States during the 10 years ending December 31, 1931, ranked third in the causes of fatal accidents; they constituted 16.2 per cent of all fatal accidents in bituminous mines and 8.4 per cent of all fatal accidents in anthracite mines. A study of coal-mine explosions in Pennsylvania, with approximately 160,000 men employed in anthracite mines and about 145,000 in bituminous mines or about 205,000 out of the approximately 525,000 men employed in all coal mines of the United States, should give information of value to all persons endeavoring to reduce or eliminate coal-mine explosions. This circular reviews explosions of gas or dust or of both in the coal mines of Pennsylvania to show the hazard of gas and dust, to point out the influence of certain factors in causing explosions, and to emphasize the efficacy of explosion-preventive measures.

The data published annually by the State Department of Mines and of the United States Bureau of Mines were used in compiling the tables of explosions. Through the cooperation of W. H. Glasgow, secretary, Department of Mines of Pennsylvania, and his assistants, many doubtful cases were clarified, so that as far as recorded the history is comparatively complete. Figures used in compiling some of the tables were furnished by W. W. Adams, chief statistician, demographical division, United States Bureau of Mines.

EXPLOSIONS IN ANTHRACITE MINES

Anthracite in the Wyoming Basin of Pennsylvania was used locally by gunsmiths in 1755, by blacksmiths in 1769, and as domestic fuel in 1808.

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1 The Bureau of Mines will welcome the reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6710."

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Mining and shipments developed slowly between 1806 and 1812, but more rapidly after that.

Early mining along the outcrops gave essentially no trouble from gas, but by 1870, when State inspection was established, explosions were frequent; ventilation was crude and accumulations of gas were generally "brushed" or burned out.

Table 1 lists 1,232 ignitions and explosions of gas in anthracite mines from 1870 to 1932, inclusive, every one of which was accompanied by loss of life. Some details are given of 110 representative cases in which five or more lives were lost or in which it appeared that some violence was present.

Fatalities[4]

During the period 1870 to 1932, inclusive, gas explosions caused 2,213 fatalities, or an average of about two deaths for each ignition or explosion. Records are not available as to the number injured in these and in other explosions where no deaths occurred, but from a study of explosion reports it appears probable that the number injured exceeds the number killed. In the 110 cases described, 599 were killed and 294 were injured. As shown in Table 2, fatalities from gas explosions averaged 8.3 percent of the total fatalities in Pennsylvania anthracite mines from 1870 to 1931, varying from 6.0 percent in 1931 to 13.1 percent in 1927.

Table 2. - Fatalities from gas explosions in anthracite mines

Period, years	Fatalities per million		Percent of total number killed
	Tons	Man-hours (surface and underground)	
1870	1.09	0.24	8.1
1871 - 1880	1.11	.23	12.3
1881 - 1890	.66	.13	7.9
1891 - 1900	.71	.14	9.8
1901 - 1910	.47	.11	6.2
1911 - 1920	.47	.12	7.3
1921 - 1925	.58	.15	10.0
1926	.68	.18	12.8
1927	.80	.22	13.1
1928	.42	.12	7.1
1929	.42	.11	6.4
1930	.59	.16	9.3
1931	.39	.11	6.0
Total	0.59	0.14	8.3

4 The number of cases and men killed differ from yearly totals given by the Bureau of Mines and the State due to the inclusion of fatalities segregated by them under other headings and some in mines not under State control.

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Case	Date	County	Type of opening	Tons per day	Men employed	Men in mine	Extent of explosion	Cause of accumulation	Source of ignition	Other factors	Possible means of prevention at time	Killed	Injured	Escaped from area uninjured	Other ignitions	Killed	Total yearly gas fatalities
1	1847 Feb. 19	Schuylkill	-	-	-	-	Small	Poor ventilation	Open light	Testing air with lamps	Ventilation, flame safety lamps	7	-	-	-	-	7
2	Aug. 26	do.	-	-	-	-	Small		Open light		Flame safety lamps	3	-	-	-	-	-
3	Summer	Luzerne	Shaft	-	-	3	Violent	Ventilation interrupted by shaft repairs	Furnace at shaft bottom		Continuous ventilation	5	-	-	-	-	-
4	1866 Autumn	do.	do.	-	16	10	do.	Fall released gas	Open light	Had finished repairs to shaft	Safety lamps	-	9	1	-	-	6
5	1870 Aug. 31	Carbon	-	200	250	-	Small	Gas commonly present	Unlocked flame safety lamp	Miner removed gauze from flame safety lamp	Ventilation and proper use of lamps	2	-	-	9	15	17
6	June 2	Schuylkill	Slope	150	110	-	Small	Insufficient ventilation	Open light		Ventilation and inspection, flame safety lamps	3	3	-	-	-	-
7	1871 Aug. 14	Luzerne	Shaft	30	25	20	-		do.		Proper ventilation and flame safety lamps	17	-	3	-	-	-
8	Oct. 2	Schuylkill	Slope	150	100	-	Small	Released by blasting	do.	Fall forced gas over lights	do.	5	1	-	11	19	44
9	1872 Feb. 8	Luzerne	Tunnel and shaft	-	40	5	Violent	Poor ventilation and open door	do.	Reopening and repairing; no inspection before men entered	Inspection and flame safety lamps	4	1	-	17	27	31
10	1873 June 10	Northumberland	Drift and slope	75	50	-	Small	Unventilated old workings	Fire boss exploring with open light	9 men on return air killed by carbon monoxide	Ventilation and flame safety lamps	10	-	-	9	18	28
	1874* 1/	-	-	-	-	-	-	-	-	-	-	-	-	-	15	33	33
11	1875 Dec. 28	Luzerne	Shaft	300	220	-	Local	Broke into old workings	Open light	Men went in from nongassy mine	Instruction, supervision, safety lamps	3	4	-	9	16	19
12	Feb. 12	do.	do.	750	240	10	do.	Ventilation repairs on idle day	do.	Men went off intake airway	Supervision and flame safety lamps	4	2	4	-	-	-
13	1876 Apr. 12	Carbon	Shaft and slope	550	320	-	do.	Ventilation, pipes changed in a heading	do.	Men went in against orders	Inspection and flame safety lamps	4	4	1	11	21	29
14	1877 May 9	Schuylkill	Shaft	850	570	-	Small	Removal of door	do.	Fall forced gas over lights	do.	7	6	4	5	9	16
15	Jan. 15	do.	Slope	500	300	-	Local	Outburst of gas	Davy flame safety lamp	Blew on flame and flame came through gauze	Proper use of lamps	5	-	-	-	-	-
16	1878 Oct. 8	Luzerne	do.	900	450	-	do.	Feeders	Fire	Rekindling of fire	Precaution in fighting fires	4	-	1	8	14	23
17	Jan. 9	do.	Shaft	400	160	3	do.	High concentration in return airway	Open light	Fire boss entered without testing air	Use of safety lamps	1	1	-	-	-	-
18	May 6	Carbon	do.	950	600	20	do.	Feeders in test hole	Fire	Extinguished flames, but coals reignited gas	Possibly sealing fires	6	2	-	-	-	-
19	1879	Luzerne	do.	1,400	820	-	Violent	Cavity in sagging roof	Open light	Gas released suddenly	Flame safety lamps	-	4	-	-	-	-
20	Nov. 2	do.	Slope	900	445	5	Local	Cave-in	do.	Timber crew went in Sunday morning; no inspection made	Flame safety lamps and inspection	5	-	-	9	17	29
21	Mar. 5	do.	do.	1,200	725	-	Small	Unventilated idle workings	do.	Fire boss and party exploring; no tests for gas	do.	6	-	-	-	-	-
22	1880 May 3	Northumberland	do.	550	400	-	do.	Gas released by run of coal	do.	Extracting pillars	Supervision, inspection, and flame safety lamps	5	-	-	6	10	21
	1881*	-	-	-	-	-	-	-	-	-	-	-	-	-	12	27	27
23	May 24	Schuylkill	do.	700	445	-	Violent	Squeeze falls blocked airway	do.	Open light in safety-lamp section	Supervision, no open lights	5	2	-	-	-	-
24	1882 June 15	Luzerne	Shaft	-	100	6	Local	Sinking shaft; pumps stopped	do.	Ventilation by exhaust of pumps only	Continuous ventilation and flame safety lamps	3	3	-	10	17	25
	1883*	-	-	-	-	-	-	-	-	-	-	-	-	-	15	28	28
25	1884 Dec. 8	Northumberland	Slope	220	170	-	Small	Cut into gas pocket	Broken flame safety lamp	Sudden inrush of gas	Care in use of flame safety lamp	4	1	2	5	8	12
26	Feb. 17	Luzerne	Shaft	350	240	-	Local	Fan stopped 20 minutes with hot bearing	Open light	Had sent in to call men out	Second or stand-by fan, flame safety lamps	2	11	-	-	-	-
27	1885 Oct. 21	do.	do.	500	380	-	do.	Reopening after being idle 9 months	do.	One gas pocket burned, second exploded	Inspection, ventilation, flame safety lamps	6	10	-	6	15	23
28	Aug. 30	Lackawanna	Slope	300	180	7	do.	Fan stopped 1 hour, and fell on slope	do.	Fire boss and 6 men went in with open lights	Inspection and flame safety lamps	6	1	-	-	-	-
29	1886 Nov. 26	Luzerne	Shaft	500	260	52	do.	Pumps stopped, sump full	do.	Man went to sump; passed danger board	Supervision, flame safety lamps	12	20	15	5	5	23
30	Mar. 30	Lackawanna	Slope and shaft	1,200	600	-	Small	Poor ventilation and inspection	do.	Gas moved over lights	Ventilation, inspection, flame safety lamps	2	5	-	-	-	-
31	1887 June 25	Luzerne	Shaft	2,000	1,000	-	do.	do.	do.	Went into uninspected working	Inspection and flame safety lamps	3	2	-	8	10	15
32	1888 Jan. 27	do.	do.	2,000	1,000	-	do.	Open door	do.	Gas carried over mason's lights	Flame safety lamps and continuous ventilation	1	3	-	12	19	20
	1889*	-	-	-	-	-	-	-	-	-	-	-	-	-	18	29	29
33	Feb. 1	do.	do.	2,000	1,000	-	Local	Cave and squeeze; repair work only	do.	No inspection, carried open lights	Inspection and flame safety lamps	8	5	-	-	-	-
34	Apr. 2	do.	Drift and slope	2,000	1,000	-	Small	Unventilated face of breast	do.	In moving gas let it go to next face	Not move gas with men in mine; safety lamps	5	4	-	-	-	-
35	1890 May 15	do.	do.	550	375	-	Strong	Cave-in blocked airway	do.	Man tried to light lamp while getting out	Prohibit matches; remove men in time	26	2	-	-	-	-
36	Aug. 20	do.	Slope	550	280	4	Violent	Surface repairs; mine idle for month	do.	Incomplete inspection; officials entered	Inspection and ventilation, flame safety lamps	4	0	0	-	-	-
37	Oct. 8	do.	Shaft and slope	1,500	600	-	Strong	Idle breast, unventilated	Blasting (dynamite)	Blast broke through into idle breast	Ventilate all open workings	2	1	-	10	15	60

1/ Years marked with an asterisk are those in which there were no major accidents, or in which no accidents occurred.

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Case	Date	County	Type of opening	Tons per day	Men employed	Men in mine	Extent of explosion	Cause of accumulation	Source of ignition	Contributing factors	Means of prevention at time	Fatalities	Serious injuries	Injured	Fatalities	Killed	Fatalities
38	1891 Nov. 8	Luzerne	Shaft	1,900	1,600	15	Strong	Changing ventilation, idle days	Davy lamp	Gas came through, "missed" crosscut	Supervision	12	2	1	-	-	-
39	Dec. 31	do.	Slope	750	375	-	Local	Repairing ventilation in idle section	do.	Strong current pulled flame through gauze	Supervision; stay on intake	2	1	0	15	25	39
40	1892 Mar. 9	do.	Shaft	1,200	650	-	do.	Air hose removed while blasting	Blasting (dynamite)	Shot two holes with battery	Ventilation	3	2	-	-	-	-
41	May 31	do.	Slope	750	400	-	do.	Insufficient ventilation	Open light	Went in ahead of fire boss inspection	Inspection, flame safety lamp	4	7	-	-	-	-
42	July 23	Schuylkill	do.	200	400	-	Strong	Gas freed by blast	Davy lamp	Lamp left in gas when men ran	More care, extinguish lights	15	-	-	-	-	-
43	Nov. 9	Luzerne	Shaft	1,000	500	-	do.	Poorly regulated ventilation being fixed	Open light	Erecting brattice, forced gas over open light	Only competent men and flame safety lamps to clear gas with others out of mine	2	3	-	27	34	58
44	1893 June 22	do.	do.	2,000	1,100	-	Violent	Driver left door open	do.	Closing door moved gas onto gangway	Double doors, flame safety lamps	5	2	-	-	-	-
45	Sept. 21	do.	Slope	1,400	650	-	Strong	Changing air	do.	Ignited by foreman	Inspection, flame safety lamps	6	2	2	19	35	46
46	1894* 1/	-	-	-	-	-	-	-	-	-	-	-	-	-	15	29	29
47	1895 Feb. 18	Schuylkill	do.	1,300	750	-	do.	Released by run of coal	Davy lamp	Strong current pulled flame through gauze	Extinguish lamps in time	5	0	0	-	-	-
48	Oct. 7	Luzerne	do.	1,000	530	-	do.	Old working not examined	Open light	Fire boss and party of young engineers	Proper inspection, flame safety lamps	7	0	3	13	19	31
49	1896 Sept. 24	Schuylkill	Shaft	300	190	-	Great violence	Gas burst released by blast	Davy lamp	Flame forced through gauze	Blast only after men are off return side and some distance away	4	1	-	-	-	-
	Oct. 29	Luzerne	do.	2,600	800	9	Violent	Temporary change in ventilation, idle day	Blasting (50% dynamite and electric battery)	Blasting for overcast; ventilation disturbed	Inspection before blasting	6	-	3	18	32	42
	1897*	-	-	-	-	-	-	-	-	-	-	-	-	-	21	36	36
50	1898 Oct. 13	Carbon	Slope	1,200	260	13	Small	Sealed area	Fire	Filling behind seals with water	Remove men when seals are in	4	7	2	19	36	40
	1899*	-	-	-	-	-	-	-	-	-	-	-	-	-	16	28	28
51	1900 Nov. 9	Schuylkill	do.	1,000	375	-	Strong	Temporary change, building overcast	Open light	Miner went into abandoned section	Ventilate all workings, flame safety lamps	7	8	-	20	31	38
52	1901 Oct. 25	Luzerne	do.	2,000	880	-	Local	Feeders lit by open light but extinguished	Fire	Coal embers reignited explosive mixture	Flame safety lamps, care with fires	6	6	-	14	27	33
53	1902 Nov. 29	Northumberland	Shaft	1,400	800	-	do.	Poorly ventilated faces	Blasting (dynamite)	Gas known to be present	Ventilation before blasting	7	5	-	9	13	20
	1903*	-	-	-	-	-	-	-	-	-	-	-	-	-	15	26	26
	1904*	-	-	-	-	-	-	-	-	-	-	-	-	-	20	30	30
54	1905 Dec. 13	do.	do.	1,100	800	-	do.	Large burst of gas	Smoking	Locked safety lamps used	No smoking	4	2	-	29	30	34
55	1906 May 14	Luzerne	Slope	1,100	590	-	Violent	Fall on gangway	Open light	Man entered workings reported clear	True reports, flame safety lamps	2	2	-	-	-	-
56	Aug. 6	do.	Shaft	1,800	1,100	-	Strong	Poor ventilation in face	Blasting (dynamite)	Electric magneto firing unit	Permissible blasting units	6	1	-	30	35	43
57	1907 Mar. 2	Lackawanna	do.	1,200	490	-	Local	Open doors	Open light	"Mine well ventilated"	Eliminate or safeguard doors; flame safety lamps	7	3	-	-	-	-
58	June 18	do.	do.	2,000	1,200	-	Strong	Stoppings blown out by first small explosion	do.	Men went back and set off second strong explosion	Supervision, flame safety lamps	7	2	3	22	30	44
59	1908 May 12	Luzerne	do.	1,100	650	-	do.	Feeders ignited and extinguished	do.	Gas carried out over men moving it	Supervision, no open lights in moving gas, and remove men when moving gas	12	11	-	31	45	57
60	1909 Mar. 2	do.	Slope	2,800	1,500	-	Local	Gas found in face, brattice men clearing it	do.	Used safety lamps, one had open light	Supervision, no open lights in moving gas, and remove men when moving gas	8	6	-	21	22	30
61	1910 Jan. 11	do.	do.	2,500	1,100	-	do.	Fall destroyed check or curtain left 16 hours	do.	Ventilation restored moved gas over open light	Remove men till section is clear, flame safety lamps	7	0	6	-	-	-
62	Mar. 12	do.	Shaft	2,500	1,200	7	do.	Idle 3 days - repairs "shorted" air	do.	Fire boss reported clear; crew went in	Inspection, no open lights	7	0	0	17	20	34
63	1911 Jan. 10	do.	do.	700	350	-	do.	Gas from abandoned breast forced on gangway	do.	Built ventilation wall moved gas over open light	Ventilation, inspection, closed lights	3	1	-	-	-	-
64	May 27	Northumberland	Slope	1,400	900	-	do.	Cut into gassy bed	do.	Men left but followed fire boss in with open lights	Supervision, closed lights	5	-	-	23	28	36
65	1912 Jan. 9	Luzerne	do.	700	400	-	Strong	Settling roof held door open	do.	Ignition set off boxes of dynamite and black powder	Closed lights, restrict amount of explosives in any one place	6	2	1	-	-	-
66	July 17	do.	Shaft	2,500	1,200	-	Local	Poor ventilation of faces	Blasting	Black powder and dynamite fired electrically	Ventilation and permissible explosives	4	0	-	28	35	45
67	Apr. 12	do.	do.	3,500	1,600	10	do.	Deranged ventilation	Open lights	Mixed lights	Ventilation, inspection, closed lights	4	3	-	-	-	-
68	1913 July 22	do.	do.	2,000	1,100	-	do.	Gas ignored; used locked safety lamps	Smoking	5 men in this known gassy section	Ventilation, no smoking	3	2	0	-	-	-
69	Aug. 2	Schuylkill	do.	1,400	900	20	Strong	Pillar failure released gas and short-circuited air	Open lights	Men leaving met gas	Supervision, closed lights	20	0	0	25	28	55
70	1914 Sept. 16	Carbon	do.	1,500	900	-	do.	Booster fan stopped overnight	Smoking	Mixed lights	Eliminate booster fans; no smoking	7	2	-	29	40	47
71	1915 Feb. 17	Luzerne	do.	2,000	1,000	-	do.	Gas from high cavities	Open lights	Brought down by a "slide in"	Ventilation, closed lights	13	3	0	15	20	33
72	Feb. 8	do.	Slope	1,500	700	-	Local	Open door	do.	Gas moved over lights when door was closed	Inspection, closed lights, continuous ventilation by use of overcasts, etc.	7	2	0	-	-	-
73	1916 Mar. 9	do.	do.	1,200	650	-	Strong	Large gas body released by blasting	Blasting, permissible and dynamite	Possible ignition by Davy lamp	Permissible shooting, approved lamps	6	1	-	-	-	-
74	Aug. 8	do.	Shaft	3,500	1,600	10	Violent	Development work only, insufficient ventilation	Defective flame safety lamp	Working on new airways	Ventilation, inspection, closed lights	6	1	-	-	-	-

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Case	Date	County	Type of opening	Tons per day	Men employed	Men in mine	Extent of explosion	Cause of accumulation	Source of ignition	Other factors	Possible means of prevention at time	Killed	Injured	Persons from area uninjured	Other ignitions	Other cases Killed	yearly gas fatalities
75	1916 Aug. 9	Luzerne	1 slope 3 shafts	2,000	1,200	-	Small	Gas from borehole; poor ventilation	Open lights	Ignited by shift coming in	Ventilation, inspection, closed lights	2	3	-	-	-	-
76	1916 Dec. 1	do.	Shaft	-	-	-	Strong	No ventilation, enlarging shaft	Blasting (50 per cent dynamite)	Reopening, all men on surface	Ventilation, inspection, permissible blasting	2	1	-	24	30	53
77	1917 Dec. 31	Lackawanna	3 shafts	1,300	600	-	Local	Open door	Open light	Man met gas which was being moved	Supervision, closed lights	1	9	-	31	44	45
	1918* 1/	-	-	-	-	-	-	-	-	-	-	-	-	-	25	28	28
78	1919 July 8	Carbon	Slope	3,000	1,600	-	do.	Gas released by blasting	Unknown	Smoking, or misuse of safety lamp	Ventilation, closed lights	8	3	-	26	40	48
	1920*	-	-	-	-	-	-	-	-	-	-	-	-	-	34	41	41
79	1921 Mar. 9	Schuylkill	Shaft	1,600	800	-	do.	Booster fan stopped overnight	Electric arc	Electricians moved fan and threw in switch	Test for gas, eliminate booster fans	5	6	3	-	-	-
80	1921 Nov. 7	do.	Slope	1,300	650	-	Small	Closed regulator from idle section	Smoking	"Closed light" mine	Supervision	4	0	-	44	56	65
	1922*	-	-	-	-	-	-	-	-	-	-	-	-	-	10	15	15
81	1923 Feb. 21	do.	Shaft	1,100	600	-	Local	Brought down raise by blasting	do.	Poor ventilation and inspection	Ventilation, inspection, prohibit smoking	5	-	-	-	-	-
82	1923 June 26	Northumberland	Slope	1,300	875	-	do.	Double doors too close to contain trip	do.	Left open for trips to pass	Proper spacing of doors, no smoking	5	-	-	30	35	45
83	1924 June 6	Luzerne	Shaft	3,000	1,250	-	do.	Replacing broken doors	do.	When broken doors replaced, gas moved over men	Inspection and supervision	14	6	-	36	42	56
84	1925 May 22	do.	do.	3,000	2,200	-	do.	Open door	Electric arc	Cable-reel locomotive	Ventilation, permissible equipment	7	1	-	-	-	-
85	1925 June 8	Carbon	Slope	3,500	1,700	-	do.	Irregular ventilation	Blasting	"Sand blast" of 25 pounds Red H permissible	Permissible blasting and adequate ventilation	4	-	-	-	-	-
86	1925 Aug. 3	Luzerne	do.	1,900	900	-	do.	Open door	Smoking	When door was closed gas moved to slope	Ventilation and supervision	10	2	-	18	22	43
87	1926 May 6	Schuylkill	do.	450	230	-	do.	Ventilation by compressed air only	Blasting (40 per cent dynamite)	By blasting or premature explosion	Ventilation and permissible blasting	5	4	-	-	-	-
88	1926 June 29	Luzerne	Shaft	8,000	1,750	-	Violent	Door open while shifting cars	Defective flame safety lamp	"Motor" crew rerailing car	Eliminate doors, inspect flame safety lamps	3	8	-	-	-	-
89	1926 July 3	do.	Slope	2,200	1,200	-	Strong	Pillar fall	do.	Gas forced over men working	Ventilate gobs, inspect flame safety lamps	7	8	-	-	-	-
90	1926 Sept. 2	Northumberland	do.	1,200	600	-	do.	Blasting blocked intake	Smoking	Gangway on return air	Ventilation and supervision	4	-	-	-	-	-
91	1926 Oct. 30	Luzerne	Shaft	3,500	2,200	-	do.	Fans stopped over holiday	do.	Starting booster fans pulled gas over men	Eliminate booster fans, no smoking	9	-	-	23	30	58
92	1927 Apr. 27	do.	do.	1,000	360	-	Local	Lack of brattices	do.	Gas gathered in hole in roof	Ventilation, no smoking	4	-	-	-	-	-
93	1927 May 26	do.	do.	4,500	1,600	-	Violent	Squeeze and fall	Unknown	Gas ignited and started fire, causing second and third explosion	Proper supervision	7	20	-	-	-	-
94	1927 Sept. 29	Lackawanna	do.	3,500	1,600	-	Local	Open doors	Electric arc	Open-type haulage locomotive	Doors in pairs, permissible equipment	4	5	-	-	-	-
95	1927 Oct. 7	Schuylkill	Slope	1,200	600	-	do.	Released by blasting	Open light	Only safety and electric cap lamps allowed by rules	Proper supervision	4	1	-	33	45	64
96	1928 May 25	Luzerne	Shaft	2,000	900	-	do.	Ventilation interrupted	Smoking or electric arc	Gas moved over men at lunch	Ventilation, no smoking, permissible equipment	10	5	-	-	-	-
97	1928 July 9	Schuylkill	Slope	1,500	750	-	do.	Face of incline not ventilated	Smoking	Closed-light mine; smoking or open light	Ventilation and supervision	3	0	4	17	19	32
	1929*	-	-	-	-	-	-	-	-	-	-	-	-	-	27	31	31
98	1929 Feb. 7	do.	do.	2,000	900	-	do.	do.	Open light	No inspection before men went up	Ventilation, inspection, closed lights	4	0	-	-	-	-
99	1929 Feb. 25	do.	Shaft	1,500	800	-	do.	Released by blasting	Blasting	Overcharged shot, permissible explosive, 10-shot battery	Inspection, permissible shooting	4	0	-	-	-	-
100	1930 Sept. 17	do.	Slope	600	190	-	do.	Feeder and poor ventilation	do.	Blow-out mixed shot, non-permissible battery	do.	4	2	-	-	-	-
101	1930 Sept. 29	Luzerne	Shaft	1,000	600	-	Strong	Falls released gas, short-circuited ventilation	Open lights	"Nongassy" mine, men ignited gas when going in	Ventilation, inspection, closed lights	4	3	0	-	-	-
102	1930 Oct. 10	do.	do.	1,200	500	-	do.	Feeder and poor ventilation	Davy lamp	Left lighted in gas which burned through gauze	Ventilation and permissible lamps	4	1	-	16	22	42
103	1931 Jan. 14	do.	Slope	175	70	-	Local	Took boards from brattice for door	Smoking	Closed lights, gas moved over men	Instruction and supervision	3	-	-	-	-	-
104	1931 May 29	Northumberland	do.	2,000	1,000	-	do.	A fall interrupted ventilation	Blasting	Blow-out shot, permissible explosive, 10-shot battery	Permissible shooting methods	5	-	-	-	-	-
105	1931 Sept. 4	Luzerne	do.	3,000	1,000	-	do.	Feeders, poor ventilation	Smoking	Gas moved over men when line brattice was replaced	Ventilation and supervision	3	1	-	-	-	-
106	1931 Oct. 24	do.	Drift	1,500	760	-	Strong	Tapped old workings	do.	6 men entombed, 2 died of burns, 2 of carbon monoxide	Supervision	4	2	-	7	8	23
107	1932 June 1	Schuylkill	Slope	-	-	-	Local	Booster fan, poor ventilation	Blasting		Proper ventilation	2	-	-	-	-	-
108	1932 July 14	Luzerne		-	-	-	do.	Line brattice about 50 feet outby face, poor ventilation	Smoking	Failure of bosses to detect gas and presence of gas ignored by chargeman	Improved ventilation, better testing for gas	2	1	-	-	-	-
109	1932 July 26	do.		-	-	-	do.		Open light		Closed lights	1	-	-	-	-	-
110	1932 Aug. 13	Schuylkill	Shaft	16	7	-	do.	Poor ventilation, gas released by rush of coal, leakage from unventilated section	Smoking	Auxiliary fan	Proper ventilation, removal of auxiliary underground fans, permissible blasting devices	0	5	2	0	0	5
	Total			149,246	73,847	229						599	294	61	2/ 1,122	1,614	2,[illegible]

1/ Years marked with an asterisk are those in which no major accidents occurred, or in which no accidents occurred.

2/ Ignitions totaled 1,232: 110 "representative" ignitions and 1,122 other ignitions.

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CAUSES OF EXPLOSIONS IN ANTHRACITE MINES

The probable causes of the 110 representative gas explosions are summarized in Table 3; the four principal causes of the explosions are open lights, smoking, explosives or blasting devices, and flame safety lamps. Causes are discussed under separate headings.

Table 3. - Causes of ignitions of gas in anthracite mines in 110 selected explosions

Cause	Explosions
Open lights	56
Smoking	18
Explosives or blasting devices	14
Flame safety lamps	12
Mine fires	4
Electric arc or spark	3
Furnace	1
Unknown	2
Total	110

Open lights.- Of the 110 cases listed, 56 were caused by open lights, and 25 of the 32 explosions occurring prior to 1890 were caused by open lights. Although the need of a safe lamp was recognized, the Davy lamp, which was invented in 1816, gave too feeble a light to make it popular. About 1890 safety lamps became more generally used and explosions from open lights became less frequent, although 9 such explosions occurred in the 10-year period from 1890 to 1899, inclusive. During the next 33 years only 22 explosions attributed to open lights occurred. One explosion was caused by a fire boss exploring unventilated workings while carrying an open light.

Safety lamps.- Davy lamps caused 12 of the listed ignitions. In 5 of these the lamps were opened or were in a defective condition; in the other 7 ignitions, flame came through the gauze as a result of leaving the lighted lamp too long in an explosive mixture or in too strong a current of air. The first record of an explosion from a Davy flame safety lamp in a Pennsylvania anthracite mine was in 1870 and the latest in 1930

Smoking.- Although smoking was practiced in earlier years, the presence of open lights eliminated it as a source of ignition because the open flame was already present. Unquestionably numerous gas ignitions were caused from smoking where flame safety lamps were used, before 1906, when the first ignition charged to smoking appears in the list; from 1906 electric cap lamps or permissible locked flame safety lamps were used extensively, so that smoking was marked as doubly dangerous and far more reprehensible, as the use of closed lights almost invariably outlaws or prohibits smoking. Of the 110 gas ignitions recorded in Table 1, 18 explosions were charged to smoking from 1906

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to 1932, inclusive; it is significant that four of the eight explosions in the anthracite mines of Pennsylvania listed for 1931 and 1932 were attributed to smoking.

Fires.- In 4 cases, fires which had been started by open lights or blasting, ignited or reignited gas when explosive mixtures re-formed.

Explosives or blasting devices.- The first case of an ignition from blasting as given in Table 1 was in 1890; from that date until 1932 there are 14 cases listed. Blasting with nonpermissible blasting units caused some of these explosions and black blasting powder, dynamite, or mixed explosives were responsible for several explosions.

Electricity.- The first important ignition from an electric arc was in 1921, another is listed in 1925, and a third in 1927; this source of ignition had been suspected in several other cases where the evidence was inconclusive. In at least 5 explosions listed under "explosives or blasting devices" the most probable cause was nonpermissible electric blasting units that gave off an electric spark.

Unknown causes.- In two other explosions no evidence of the source of ignition was found, but in both an open flame is indicated. All of the 110 cases cited were thought to be ignitions and explosions of methane; it would appear that this hazard should be fully recognized, but in spite of this knowledge, open lights, smoking, nonpermissible blasting devices and explosives, and "safety" lamps that have proved themselves unsafe have been allowed to remain in some anthracite mines. Probably 100 of the 110 explosions listed in Table 3 were caused by open type or other recognized unsafe equipment.

CAUSES OF GAS ACCUMULATIONS IN ANTHRACITE MINES

The need for properly controlled ventilation as a prerequisite in preventing gas explosions is evident, but many explosions are the direct result of violating good ventilation practices. The causes directly accountable for the accumulation of gas responsible for the 110 explosions cited have been correlated in Table 4, showing the number of accumulations by major causes and subdivided into minor causes. The largest number of accumulations was the direct result of insufficient or interrupted ventilation. Falls or slides of roof or coal rank second in causes of accumulations of gas, open doors rank third, feeders and outbursts of gas fourth, blasting fifth, and fans sixth. The major groups that cause gas accumulation are discussed in more detail to emphasize the underlying causes of failure to remove or dilute explosive gas in the anthracite mines of Pennsylvania.

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Table 4.- Causes of gas accumulations in Pennsylvania anthracite mines - 1847 to 1932

Causes of accumulations	Number
Insufficient or interrupted ventilation	47
Changes in ventilation	13
Insufficient ventilation	13
Ventilation not carried to face	8
Lack of ventilation	6
Ventilation interrupted	3
No brattice or brattice not in place	3
Gas from bore hole not diluted	1
Falls or slides of roof or coal	18
Squeeze or fall blocked airway	7
Fall released gas	5
Gas released by run of coal	4
Fall in old workings forced out gas	1
Squeeze and fall released gas	1
Open doors	14
Door left open	8
Removal of door	1
Settling roof held door open	1
Door in stopping left open	1
Double doors, too close to contain trip, left open	1
Repairing broken door	1
Door open while shifting cars	1
Feeders and outbursts of gas	11
Feeders at face	3
Gas in old workings released when tapped in mining	3
Gas burst from coal	2
Feeders in test hole	1
Feeders in sealed area	1
Gas released when gassy bed was cut into	1
Blasting	8
Gas released by blasting	7
Blasting blocked intake airway	1
Fans	6
Booster fan idle overnight	2
Fan stopped 20 minutes with hot bearing	1
Fan stopped 1 hour	1
Fans stopped over holiday	1
Booster fan not delivering enough air	1

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Table 4.- Causes of gas accumulations in Pennsylvania anthracite mines - 1847 to 1932--Continued

Causes of accumulations	Number
Miscellaneous causes	4
Sump filled and man entered past danger board	1
Old workings entered, not ventilated, no examination	1
Presence of gas ignored	1
Unknown	1
Change of ventilation by unauthorized persons	2
Regulator closed	1
Boards removed from brattice to use in door	1
Total	110

Insufficient or interrupted ventilation.- Probably all failures to "dilute, render harmless, and remove gas" could be attributed to insufficient ventilation; however, the 47 cases segregated under this heading are due wholly to the causes named. Changes in ventilation, causing 13 accumulations, consisted of changing ventilation pipes, removing air hose during blasting, changing regulators, erecting brattice, extending line brattice, and similar methods to remove bodies of gas. A like number of accumulations, 13, were caused by failure to supply sufficient air to remove gas as it was liberated. Gas accumulated at faces of workings that were not ventilated prior to 8 explosions of gas. Failure to ventilate or seal abandoned or idle workings caused 6 accumulations of gas that resulted in explosions. Interruption of ventilation and failure to put up brattices or to replace brattices each caused 3 gas accumulations. One explosion was caused by failure to dilute gas issuing from a bore hole.

The United States Bureau of Mines considers all coal mines gassy because even where little or no gas has been detected, sudden outbursts or release of gas has occurred. Therefore, air should be so conducted that a strong current will sweep every working face and enough air will be conducted through all open workings to prevent gas accumulations. In removing gas accumulations, safe practice demands that all persons be removed from the mine or at least from the return-air side of the gas accumulations during the moving process.

Falls or slides of roof or coal.- Eighteen gas accumulations were caused by falls or slides of roof or coal which disrupted the ventilation or releasing quantities of methane. Squeezes or falls, blocking airways, resulted in gas accumulating prior to 7 explosions. Falls of roof or coal released large volumes of gas in 5 cases, run of coal released gas in 4 cases, a fall in old workings released gas in 1 case, and a squeeze and a fall of roof also released gas in 1 case. Where it is known or even suspected that gas may be released in case of falls, squeezes, coal runs, etc., good mining practice should demand that possible sources of ignition such as open lights, blasting, electric sparks or arcs should be held to a minimum.

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Open doors.- In 14 cases, open doors resulted in gas accumulations; doors being left open caused 8 of these accumulations and an accumulation was caused in each case by removal of a door, roof settling and holding a door open, a door in a stopping being left open, doors in an air lock being too close to allow a trip to pass without both doors being open, and a door left open while cars were being shifted.

Feeders and outbursts of gas.- In some mines a large amount of the gas is liberated from feeders, and in 11 of the cases cited, feeders or outbursts of gas caused accumulations; at least 5 of these were the result of uncovering feeders, and the other 6 were caused by gas rushing from old workings, or from outbursts from gas in beds under pressure.

Blasting.- In many mines considerable gas is released by blasting and at times feeders or bodies of gas are released; in 7 of the cases cited release of explosive gas by blasting was the cause of accumulations, and in one case blasting blocked an airway, cutting off ventilation. By all means blasting should, if possible, be done when the working shift is not in the mine or at least not in the immediate vicinity or on the return side of the place or places where blasting is done.

Fans.- Failure, in some manner, of fans caused at least 6 accumulations of gas; 5 of these were due to shutting down of so-called auxiliary fans, and 1 was caused by a booster fan not delivering enough air. Auxiliary fans used underground are, in most cases, an admission that the ventilating system is inefficient.

Changes in ventilation by unauthorized persons.- Changes in ventilation by unauthorized persons is a far too common cause of inadequate mine ventilation, although Table 1 cites only two cases: tampering with a regulator and demolishing a brattice to obtain timber. It is possible that a number of the cases listed under insufficient ventilation may be attributed to this cause.

Miscellaneous causes.- In 3 of the 4 miscellaneous cases of gas accumulations the presence of gas was known, and precautions were taken to warn workmen, who disregarded the warnings. Disregarding danger signs is by no means an unusual occurrence; however, these violations clearly show the need of ventilating all places that are not sealed, and also the need of education of the workers and of more effective supervision by management.

PREVENTION OF EXPLOSIONS IN ANTHRACITE MINES

Explosions in Pennsylvania mines are generally investigated by State mine inspectors and by trained safety investigators of the United States Bureau of Mines. The recommendations made by these men are based on wide experience and mature judgment; therefore such suggestions should be given full consideration. The methods recommended for preventing the explosions in anthracite mines as given in Table 1 are listed in Table 5.

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Table 5.- Methods recommended for preventing explosions listed in Table 1 in anthracite mines at the time of the explosions

Recommendations	Times recommended
Ventilate mine or improve ventilation	39
Use or proper use of flame safety lamps	39
Inspection, or improve inspection methods	29
Supervision	22
Use permissible (closed) lights	18
Use permissible explosives and blasting units	9
No smoking	8
Eliminate auxiliary fans underground	3
Instruction of employees	3
Use permissible electric equipment	3
Remove men from return air when moving gas	2
Eliminate doors by building overcasts	2
Use only safety lamps in moving gas	2
Proper spacing of doors in air locks	2
Precautions in fighting mine fires	1
Remove workmen from mine after erecting seals	1
Seal fires that cannot be fought directly	1
Provide second or stand-by fan on surface	1
Prohibit matches underground	1
Ventilate all open workings	1
Use double doors	1
Blast only when men are off return air	1
Make true reports of gas detected	1
Remove men until section is clear of gas	1
Restrict amount of explosives in one man's possession	1
Test for gas	1
Ventilate gobs	1

Ventilation.- Greatest emphasis has been placed on adequate ventilation, this recommendation having been made 39 times in the reports on the 110 explosions listed in Table 1 and probably should have been made in many additional instances. It has been shown that failure to ventilate, interruption of ventilation, failure to conduct air to the faces or failure to provide sufficient air allowed gas to accumulate in 78 of the 110 cases cited. In 16 others pockets or feeders of gas were released, by cutting into abandoned areas or gassy beds or by blasting, in amounts so large that the normal air currents could not properly dilute the gas; here the obvious remedy is that in mines where gas may be expected in fairly large quantities, ignition agencies should be eliminated or at least very definitely restricted or safeguarded. In 6 instances, standing gas in unventilated old workings was ignited in place or when moved over open lights.

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In view of these facts the logical conclusion is that all open parts of the mine should be ventilated by a colume of air that will not only "dilute, render harmless, and remove" gas under normal conditions, but also will be sufficient to "render harmless" sudden outbursts of gas; this requires the elimination of doors wherever possible, construction of tight stoppings, erection of effective line brattices, and construction of tight overcasts. All abandoned areas should be securely sealed, if practicable, and if they cannot be sealed they certainly should be adequately ventilated.

Flame safety lamps.- The use of flame safety lamps in explosion prevention evidently has been considered of equal importance with ventilation, each recommendation being made 39 times (see Table 5). The Davy flame safety lamp has been by no means a dependable safeguard, but when carefully used it helped to reduce probability of occurrence of explosions in its day. In 1886, a State inspector cites a case of two men killed by a burst of gas and coal: "Due to use of safety lamps, there was no explosion, which saved the loss of all the men in the mine that night." With the development of the modern approved flame safety lamp and electric cap lamp, explosions due to ignition by open lights should have ceased, though they have not done so by any means.

The Davy flame safety lamp has served its purpose; now, safer and more effective lamps are available, and unquestionably they should be used. At least one explosion was caused by an employee disassembling a flame safety lamp; if the up-to-date or permissible flame safety lamp is used, its magnetic lock should prevent unauthorized opening. The up-to-date permissible flame safety lamp also has double gauzes wherever gauzes are used, and prevention of gas ignition is not dependent on a single gauze in some parts as is the case with most Davy lamps; the propagation of flame to the surrounding gassy atmosphere by a Davy lamp, as was the case in one of the explosions listed, probably was the result of using a single gauze. Flame safety lamps must be handled properly and should be used only by a carefully trained employee; if carefully manipulated they may serve as a means to detect explosive gas and prevent explosions; unless extreme care is exercised in their use, flame safety lamps become an additional explosion hazard. Hundreds of lives have been sacrified in coal-mine explosions in the United States, and in other countries as well, started through misuse of flame safety lamps.

Inspection.- Table 5 shows that in 29 cases inspection or improved inspection methods were recommended as a means of preventing explosions which have been listed in Table 1 as having occurred in the anthracite mines of Pennsylvania. Hundreds of ignitions, resulting in fatal injuries, have occurred in Pennsylvania anthracite mines when men, many of them officials and fire bosses, went into unventilated, uninspected workings with open lights.

Inspection to be effective must be a conscientious, inflexible, rigid, well-planned procedure, not to be disregarded or slighted by officials or by workers. Numerous explosions have been started by fire bosses or other officials who carried flame safety lamps, simultaneously wearing open lights, and entering uninspected, unventilated workings. To prevent gas ignitions

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in anthracite mines, inspectors should be assured that their eyesight is sufficiently acute to determine a gas cap and then should test, thoroughly, with a properly assembled permissible flame safety lamp with a properly adjusted flame, and under no circumstances should open flame lamps be lighted or electrical equipment (especially open-type electrical equipment) be operated or shots be fired until the absence of dangerous, gassy mixtures is assured. The proper coursing of the air currents should be determined while testing for gas is in progress and careful inspection should be made as to sources of ignition, such as open flames, or electric arcs and sparks, to eliminate explosion hazards at their sources. Searching employees for matches, igniters, and smoking materials should be an important duty of inspectors and the search should be rigid, thorough and if possible made under surprise conditions, as many explosions are started by deliberate violation of "no smoking" rules.

Supervision.- In Table 5 supervision ranks fourth in the number of recommendations made for preventing explosions. Supervision is the basis of all safety efforts and is wholly responsible for effectiveness of ventilation, for the presence or absence of sources of ignition, and for inspection to determine presence of matches, igniters, open lights, the use of nonpermissible explosives and blasting devices, and nonpermissible electrical equipment or of permissible or nonpermissible equipment in a state of poor repair.

Study of data in the foregoing tables concerning explosions which have occurred in anthracite mines reveals that the number of fatalities from explosions varies with the number of ignitions in the ratio of approximately 2 to 1; in this, incipient ignitions or explosions in anthracite mines are by no means as destructive as in bituminous mines.

A notable decrease in fatalities from explosions followed supervision of anthracite mines by State mine inspectors from 1870 to 1888; an increase in fatalities then followed, essentially paralleling increase in production from 1889 to 1927, broken only by extended idle periods from strikes in 1902, 1906, 1922, and 1925. The introduction of permissible (closed) lights in the more dangerous sections of the mines of some of the more progressive companies may be responsible in part for the temporary lowering of the number killed in explosions from 1916 to 1923. The marked decline in the fatality rate from explosions in anthracite mines since 1927 (see Table 2) has been due largely to improved ventilation and to the extension of the use of permissible electric cap lamps, of permissible flame safety lamps, of permissible explosives, and of electric firing of blasts; also, it has probably been aided by more intensive supervision in an effort to conform more closely to the State law, by the added influence of compensation measures, and by the pressure of economic conditions.

Permissible (closed) lights.- Approximately half of the explosions listed in Table 1 were caused by open lights, yet the use of closed lights was recommended only 18 times; undoubtedly failure to recommend closed lights prior to 1910 was due to the fact that in those days about the only closed light available was the flame safety lamp with its poor illuminating features and clumsiness for ordinary use. It is interesting to observe that electric (safety)

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cap lamps were first used and developed in the United States in the anthracite mines by the Philadelphia & Reading Coal & Iron Co. during 1908. This company, according to J. T. Jennings, "awoke to the dangers and disadvantages of the open-flame miners' lamp, and considering the benefits in safety, efficiency, and cleanliness an electric lamp would have over the ordinary open-flame oil lamp in the hands of a miner" made a "canvass of the United States (that) showed that no electric miners' lamp existed at that time." The electrical department of the company then developed a satisfactory lamp. The permissible electric cap lamp, if used in conjunction with adequate ventilation should eliminate from anthracite mines any gas explosions caused by open lights.

In 1912, one large company had 1,500 safety lamps in use, after 5 years of pioneer experimentation; in 1932, approximately 33,000 electric cap lamps were in use in anthracite mines.

Smoking.- At least 15 explosions have been caused by smoking, yet only 8 recommendations to prohibit smoking and the carrying of smoker's accessories such as matches and patented lighters or igniters have been made in reports on the 110 explosions listed in Table 1; it is significant that two of the explosions from smoking occurred in 1932. As a source of ignition in anthracite mines, it is as important as open lights and other open-type equipment; therefore, smoking should be prohibited in all anthracite mines—in fact, in any underground mine; and the most determined effort should be made to enforce the rule at all times, particularly as regards smoking by mine officials.

Permissible explosives and blasting units.- As long as open lights were used, few ignitions resulted from blasting, because the lights generally ignited the gas before the shots were fired, although gas released by blasting was occasionally ignited by the shots, and in numerous instances gas liberated by shots and carried by air currents was ignited by open lights. With growth of the use of closed lights, ignitions through or at time of blasting became more common. The introduction of permissible explosives and electric blasting helped to limit these occurrences in anthracite mines, but the use of fuse, squib, and nonapproved blasting units, and overcharged and tight holes or holes with little or no stemming left loopholes, and explosions due to blasting continue to occur. Electric blasting is safer than firing shots with fuse or squib, but explosions have been caused by nonpermissible multiple blasting units or by using the power lines in blasting. The growth of permissible explosives in anthracite mines is shown in the following tabulation.

Types of explosives used in anthracite mines, pounds

Year	Black blasting powder	Dynamite	Permissible explosives
1917	35,754,225	16,074,125	7,298,925
1931	10,289,300	15,569,820	15,608,235

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EXPLOSIONS IN BITUMINOUS MINES

Practically from the time of the earliest settlement in Pennsylvania, coal has been mined from outcrops for local and domestic use; the garrison of Fort Pitt mined coal on the banks of the Monongahela River in 1760 for its own use, and in 1786 mining was done under the authority of William Penn in the same locality. In 1845, some coke was produced and used in making iron. In 1842, coal production was about 500,000 tons, in 1850 about 1,000,000 tons, and in 1877, when the first bituminous inspectors were appointed, about 14,000,000 tons.

Mines were mainly drifts from the outcrops, with but little gas hazard, though in 1877 and 1878 several ignitions were reported which did not result in fatalities.

Table 6 lists 170 explosions of various kinds in the bituminous coal mines of Pennsylvania of which record is available from 1878 to 1932, inclusive; of these, 85 are described in more or less detail as being explosions in which there was marked violence, or in which several were killed by burns or afterdamp. Small ignitions are grouped in the last three columns of Table 6 as other cases in the yearly totals.

Fatalities[5]

Available records as listed in Table 6 extending from 1878 to Jan. 1, 1933, show that 170 gas and dust explosions in Pennsylvania bituminous mines resulted in 1,984 fatalities or an average of about 12 fatalities in each explosion; the number killed in any one explosion ranged from 0 to 239. In scattered cases the injuries are considerable, but compared with the deaths, the number is small except possibly in the earliest years.

Table 7 presents the gas and dust fatality rates per ton and per million man-hours of surface and underground work; the rates are remarkable for the wide variation and in particular for the fine showing in the last two years. The rate based on man-hours follows the fatality rate in general trend, though it reflects the influence of increased efficiency in production. To 1895, the ratio of the two rates is about 3 to 1, then is approximately 2 to 1 until 1925; from that date the ratio gradually decreases, dropping to about 1.5 to 1 in 1930 and the ratio is 2 to 1 for the entire period 1879 to 1931, inclusive. Gas and dust explosion fatalities averaged 12 per cent of the total killed in the bituminous mines of Pennsylvania over the entire period 1879 to 1931, inclusive.

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5 See reference 4, page 2.

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Case	Date	County	Type of mine	Tons per day	Men		Explosion			Cause of accumulation	Source of ignition	Other factors	Possible means of prevention at time	Killed	Injured	Escaped area uninjured	Ignitions	Explosions	Fatalities
					Average	In mine	Type	Extent	Limited by										
	1878* 1/	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
1	1879 Dec. 29	Westmoreland	Drift, gassy	90	150	Few	Gas	Small	Amount of gas	Leaky stoppings, open door	Open light	Men going in, no inspection	Ventilation, inspection, flame safety lamps	3	-	-	2	2	5
	1880*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1
2	1881 Oct. 17	Washington	do.	225	135	-	do.	Local	do.	Feeder and open door	do.	Door closed, gas forced over lights	Supervision and flame safety lamps	1	-	2	2	2	3
	1882*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	8	8
	1883*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1
3	Feb. 20	Fayette	Shaft, new	300	90	-	Gas (?)	Moderate	Little dust, weak start	Poor ventilation and inspection	do.	Gas ignored in idle rooms	Ventilation, inspection, flame safety lamps	19	1	-	-	-	-
4	Apr. 14	Allegheny	Drift, gassy	100	175	2	do.	do.	do.	Open door, no inspection	do.	Men going to work	Inspection and flame safety lamps	2	0	0	-	-	-
5	1884 Oct. 27	Fayette	Slope, gassy	300	105	-	do.	Strong	Probably some dust fired	Open door, no inspection, idle section	do.	Door closed, gas forced over lamps	Ventilation and inspection of idle workings, flame safety lamps	14	4	2	0	0	35
	1885*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1
6	1886 Mar. 8	do.	do.	150	65	25	do.	do.	Little violence	Standing gas in idle mine	do.	Cut through from this mine	Care in approaching old workings, flame safety lamps	6	10	-	-	-	6
	1887*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	5	5
7	1888 Nov. 3	Clinton	Drift, new, no gas	150	130	-	Dust	do.	Low violence and expansion	Post fell on box of detonators, set off dynamite and black powder	Dynamite explosion	First recognized dust explosion in Pennsylvania	Keep detonators and explosives apart	17	2	5	1	1	18
8	1889 May 10	Allegheny	Drift, gassy	500	200	4	Gas and dust	Violent	Lack of oxygen	Mine idle, fan stopped 10 days	Open light	4 men went to get tools	Supervision and flame safety lamps	4	0	0	2	2	6
	1890*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
9	1891 Jan. 27	Westmoreland	Shaft, gassy (1885)	1,000	450	-	do.	Small	Low violence and impure dust	Fall and feeder after fire boss inspection	do.	Shift going in; most killed by carbon monoxide	More inspection and flame safety lamps	109	-	-	2	2	111
	1892*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1
	1893*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1
	1894*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
	1895*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4	4
10	Mar. 22	Clearfield	Shaft, gassy (1893)	100	60	13	do.	do.	do.	Feeder ignited by shot, blew itself out	Fire	Explosive mixture set off by coals	Inspection, care of fires	13	0	0	-	-	-
11	1896 June 29	Fayette	Slope, gassy	700	170	2	do.	Violent	Impure dust	Mine idle, fan stopped 20 days	Open light	2 men went in for tools by 2 danger boards	Supervision and flame safety lamps (?)	2	0	0	2	2	17
	1897*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	2
12	1898 Sept. 23	do.	Drift, gassy	500	130	-	Gas	Light	Small volume	Fan run part time only	do.	Gas over falls reported but not removed	Removal of gas and use of flame safety lamps	8	-	-	3	4	12
13	July 24	do.	Shaft, gassy	800	115	-	do.	Small	do.	Idle room, gas reported but not removed	do.	Mixed lights, man went over danger board	do.	5	2	-	-	-	-
14	1899 Dec. 23	do.	Shaft, new, no gas	210	80	30	Gas and dust	Violent	Wrecked shaft and one side of mine	Fan stopped or door open	do.	No inspection before men entered	Inspection and flame safety lamps	19	4	6	3	5	29
15	1900 Nov. 20	Washington	Shaft, gassy	80	75	-	do.	Strong	Weak start, expansion	Poor ventilation of faces	Blasting	Hole on solid fired in gas against orders, dynamite	Ventilation and safer shooting practice	3	2	-	3	5	8
16	Mar. 25	Fayette	do.	350	200	-	Gas	Local	Small volume	Careless ventilation	Blown-out shot	Shot in gas and against orders, dynamite	do.	4	0	-	-	-	-
17	1901 June 10	Westmoreland	do.	500	110	-	Gas and dust	2 explosions and fire	Low violence and expansion	Ventilation short-circuited by squeeze, gas ignited, blew out stoppings	Open light	First killed 4 men, set fire, second killed 15 rescuers	Ventilation and flame safety lamps	19	0	0	3	5	28
18	Mar. 6	Washington	Drift, gassy	1,000	225	-	Gas	Strong	Lack of oxygen	Behind fire seals	Mine fire	Opened seals in 48 hours	Leave fires sealed until extinguished	5	2	-	-	-	-
19	1902 July 10	Cambria	do.	1,900	550	-	Gas and dust	Small	Low violence, expansion	Unventilated old workings	Open light	Moved into working area by pillar removal	Ventilation or sealing of old workings, flame safety lamps	112	-	18	-	-	-
20	Dec. 24	Fayette	do.	1,000	170	4	Gas	Strong	On entry, lack of dust	Mine and fan stopped 5 days, danger board up	do.	Men went in without inspection	Ventilate and inspect before men go in, flame safety lamps	4	0	0	4	5	126
21	May 26	Allegheny	Drift, new, no gas	350	125	-	do.	Small	Small volume expansion	Poor face ventilation and door off 2 weeks	do.	No inspection	Ventilation, inspection, flame safety lamps	4	3	-	-	-	-
22	1903 Nov. 21	Fayette	Drift, gassy	.375	110	20	do.	Light	do.	Sealed fire area	Sealed fire	Pillar removal let air in, killed by CO	Leave sufficient pillars	17	3	0	1	2	23
23	1904 Jan. 25	Allegheny	Shaft, gassy	450	280	180	Gas and dust	Violent	2 men outside and 2 rescuers killed	Ice choked air shaft, poor inspection	Blown-out shot	No open lights, dusty, dynamite shot electrically	Inspection, dust control, safer shooting	179	1	0	3	5	184
24	Apr. 27	Clearfield	do.	2,100	800	-	do.	do.	Lack of dust and expansion	Open door	do.	Black powder, no inspection	Safer shooting	13	1	0	-	-	-
25	July 6	Fayette	Slope and shaft, new, no gas	20	50	-	Gas	Strong	In shaft	Platform for concreting 72 feet up	Open light	No ventilation or inspection	Ventilation and closed lights	6	-	-	-	-	-
26	1905 Oct. 29	Washington	do. gassy	600	200	-	do.	Moderate	Low violence	Sealed fire area	Sealed fire	Opened 2 seals	Precautions with fires	5	1	-	-	-	-
27	Nov. 15	do.	do. no gas	0	15	10	do.	do.	In shaft	Platform put in 50 feet down	Open light	No ventilation or inspection	Ventilation, inspection, closed lights	7	3	-	4	6	37

1/ Years marked with an asterisk are those in which there were no major accidents, or in which no accidents occurred.

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Case	Date	County	Type of mine	Tons per day	Men: Average	Men: In mine	Explosion: Type	Explosion: Extent	Explosion: Limited by	Cause of accumulation	Source of ignition	Other factors	Possible means of prevention at time	Killed	Injured	Escaped from area uninjured	Other fatalities	Gases: Killed	Total yearly fatalities
28	1906 Oct. 24	Cambria	Drift, gassy	3,000	850	-	Gas	Small	Small volume	Cars left in door	Blown-out shot	Dynamite shot with electric battery	Split ventilation and safe explosives	7	0	0	4	4	11
29	1907 Dec. 1	Fayette	Shaft and slope, gassy	1,800	340	54	Gas and dust	Violent	Expansion	Poor ventilation and inspection	Blown-out shot	Black powder, possibly arc from trolley	Permissible explosives, ventilation, inspection	34	0	0	-	-	-
30	Dec. 19	Westmoreland	do.	1,500	400	-	do.	do.	do.	do.	Open light	Went into fenced-off gassy room	Ventilation and closed lights	239	1	0	4	4	277
31	1908 Apr. 23	Washington	Shaft, gassy	1,500	600	-	Gas	Local	Small volume	Open door	Open lights	Men coming out, pumper went in	Split ventilation and closed lights	4	-	0	-	-	-
32	June 19	do.	do.	1,500	600	-	do.	do.	do.	Released by fall	do.	Moved over pillar workers	Inspection and closed lights	3	9	-	-	-	-
33	Nov. 28	do.	Shaft, mixed lights, gassy	350	225	155	Gas and dust	Violent	Throughout mine	Poor face ventilation	Blown-out shot	Nonpermissible explosives and coal-dust stemming	Permissible shooting, ventilation and inspection	154	1	0	1	1	162
34	1909 Jan. 25	Somerset	Slope, gassy	700	320	-	Gas	Local	Low violence	Feeders when pillar work started	Open light	Ignited on day shift, night shift going in	Inspection and closed lights	5	-	-	-	-	-
35	Jan. 29	Westmoreland	do.	700	300	-	Gas and dust	Small	Low force and dampness	Small amount from floor crack	do.	Ignited by machineman	Testing by cutters, closed lights	2	2	1	-	-	-
36	Apr. 9	Somerset	Drift, no gas	350	150	-	Dust	do.	Expansion and impure dust at entries	Shooting top for overcast	Blown-out shot	Dynamite overcharged and misplaced	Wet dust, safer shooting	7	0	0	-	-	-
37	June 23	Indiana	Shaft, slope, no gas	1,300	500	-	do.	Strong	Wet sections and expansion	Hole blown out night before	do.	Shot 2 sticks of dynamite untamped	Safer shooting	21	12	-	-	-	-
38	Oct. 31	Cambria	do.	1,500	600	28	do.	do.	do.	Idle day, miner shot 2 holes off solid	do.	Shot dynamite in 1 foot of coal	do.	16	1	-	2	2	53
39	1910 Feb. 5	Indiana	Drift, gassy	700	200	-	Gas and dust	do.	Wetness	Idle room, gas allowed to stand	Open light	Miner went in	Inspection, ventilation, and closed lights	11	8	-	-	-	-
40	Oct. 16	Allegheny	do.	350	100	0	do.	do.	Wetness and low force	Fan shut down after shooting, for repairs	Probably burning feeder	Blew up 15 hours later	Inspection and spare fan	0	0	0	3	4	15
41	1911 July 15	Jefferson	Shaft, open light, gassy	1,000	270	29	do.	Violent, one side of mine	Wetness and impure dust	Unventilated face	Blasting	Mixed safety explosives and black powder	Ventilation, inspection, and safer shooting	21	0	0	-	-	-
42	Nov. 9	do.	Slope, gassy	1,500	600	-	do.	Strong	Little or no available expansion	Poor ventilation	Electric arc	Trolley wire under fall	Ventilation and wet dust	8	0	4	0	0	29
	1912* 1/	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1
43	1913 Apr. 23	Washington	Drift, gassy	700	200	167	do.	Violent	Use of water and salt and expansion	Brushing gas out of room to fire shot	Open light	Apparatus man killed by CO	Closed lights and proper ventilation	98	0	3	0	0	98
44	1914 Oct. 26	Allegheny	Slope, open lights, gassy	1,500	415	0	do.	Strong	Expansion and patches of water	Fan idle over Sunday, power thrown on	Electric arc	Pump motor on, recovery worker killed	Continuous ventilation, rock-dusting	1	0	0	1	2	3
45	1915 May 24	Cambria	Slope, no gas	350	100	8	do.	do.	Weak start	Rock shot or poor ventilation and door open	Open light	Apparatus man killed by CO	Ventilation, closed lights and rock-dusting	9	0	0	-	-	-
46	July 1	Fayette	Slope, gassy	400	100	-	do.	600 ft., small	Weak start, very wet mine	Idle section poorly ventilated	do.	Pumper went in, no inspection made	Ventilation, inspection, closed lights, and rock-dusting	1	0	0	-	-	-
47	Aug. 31	Somerset	do.	1,500	500	-	Gas	do.	Small amount	Cavity in roof	Arc from trolley	Gas distributed when door opened	Ventilation, restrict power wires	19	8	-	1	1	30
48	1916 Feb. 11	Indiana	Drift, mixed lights, gassy	2,000	350	-	Gas and dust	do.	Weak start and dampness	Released by pillar falls	Open light	Falls not inspected	Closed lights, inspection, rock-dusting	27	4	-	-	-	-
49	Mar. 30	Westmoreland	Shaft, slope, new, no gas	150	38	8	do.	Entire mine	Entire mine	Poor ventilation and no inspection	do.	Possibly another source	Ventilation, inspection, closed lights, rock-dusting	8	0	0	-	-	-
50	Oct. 21	Jefferson	Slope, gassy	2,200	400	0	Gas and dust	Strong	Expansion and wet areas	Idle, one fan stopped, insufficient ventilation	Electric arc	Usually 100 men in part affected	Cut off current when idle, and rock-dust	0	0	0	1	1	36
51	Mar. 13	Washington	Shaft, gassy	950	225	-	do.	do.	Impure dust and dampness	Open door and poor inspection	do.	Nipping, traveling machine	Split ventilation, inspection, storage-battery machine, rock-dust	14	-	24	-	-	-
52	1917 Mar. 18	Fayette	do.	1,500	400	5	do.	do.	Dampness and expansion	Raised curtain and hole in pillar	do.	Nipping or pump motor	Proper stoppings, inspection, and rock-dust	4	0	0	-	-	-
53	Apr. 3	Westmoreland	Slope, non-gassy	100	41	3	do.	do.	Dampness on mains and expansion	Lack of air at faces, no inspection made	do.	Nonpermissible mining machine	Test by cutters, permissible machines, rock-dust	3	0	0	0	0	21
54	Mar. 16	Armstrong	Drift, non-gassy	20	7	7	Dust	do.	Entire mine except air course	Shot off solid, coal-dust tamping	Blown-out shot	Black powder and squib	Permissible shooting and rock-dust	4	0	3	-	-	-
55	1918 Aug. 7	Allegheny	Shaft, small, non-gassy	50	30	-	Gas	do.	Wet, just reopened and pumped out	Almost no ventilation	Open light	No inspection	Ventilation, inspection, closed lights	8	0	0	0	0	12

1/ Years marked with an asterisk are those in which there were no major accidents, or in which no accidents occurred.

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Case	Date	County	Type of mine	Tons per day	Men Average	Men In mine	Explosion Type	Explosion Extent	Explosion Limited by	Cause of accumulation	Source of ignition	Other factors	Possible means of prevention at time	Killed	Injured	Injured from areas uninjured	Other cases Ignitions	Other cases Killed	Yearly fatalities
56	Jan. 20	Clearfield	Slope, nongassy	25	20	-	Gas	Small	Small volume of water	Water rose and cut off air shaft	Open light	Moved into entry by blasting	Inspection and closed lights	3	-	-	-	-	-
57	1919 Mar. 17	Westmoreland	Drift, gassy	1,500	250	-	do.	Local	Floor covered with water	Door open	do.	Lack of inspection	Inspection, split ventilation, closed lights	3	-	-	-	-	-
58	Oct. 8	do.	Drift, nongassy	800	220	-	do.	do.	Low violence	Pillar cave broke surface gas line	do.	Gas pulled in by exhaust fan	Mapping and care of pipe lines	2	2	12	1	2	10
59	1920 June 2	Washington	Sinking shaft, gassy	0	6	6	do.	Violent	Shaft just reached coal	Closed lights and poor ventilation	Unknown	Probably smoking	Ventilation, inspection, supervision	6	0	0	-	-	-
60	June 7	Indiana	Drift, gassy	125	50	-	do.	Local	Mine very wet, roopening	Stoppings broken, repairing	Open light	Closing holes moved gas over crew	Closed lights and supervision	2	3	-	-	-	-
61	1920 June 13	Armstrong	Drift, nongassy	350	125	2	do.	do.	Small volume	Fan stopped Saturday, run Sunday with open door	do.	Machine crew, no inspection	Inspection and closed lights	2	0	0	-	-	-
62	July 19	Allegheny	Sinking shaft, gassy	1,700	325	9	Gas and dust	Violent, entire mine	Entire mine	Fan repairs, 2 days	Electric arc	Fire boss took "motor" in on run	Inspect before men enter and rock-dust	9	0	0	3	3	22
63	1921 May 23	Cambria	Drift, nongassy	600	100	-	do.	Strong	Dampness and expansion	Door open and lack of inspection	Open light	Men going in	Split ventilation, inspection, closed lights, and rock-dust	2	-	-	0	0	2
64	Feb. 2	Fayette	Shaft, gassy	2,500	400	29	do.	do.	do.	Idle day, gas in face, no testing	Electric arc	Firing wires, third shot gas and dust	Permissible firing, ventilation, rock-dust	25	0	0	-	-	-
65	1922 Mar. 20	Indiana	Drift, gassy	700	150	-	Gas	Small	Low violence	Fan idle Sunday, fire boss skipped section	do.	Closed lights, open-type room hoist	Inspection and permissible equipment	5	3	-	-	-	-
66	Nov. 6	Cambria	Shaft, nongassy	500	117	-	Gas and dust	Moderate	Low violence and wet patches	Poor ventilation and inspection	Open light	Moved over lights (?)	Closed lights, ventilation, inspection, and rock-dust	77	22	11	1	1	108
	1923* 1/	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
67	Jan. 26	Indiana	Slope, gassy	200	50	47	do.	Strong	Expansion and inert dust on old roads	Faces ahead of air, poor ventilation and inspection	Mining machine (electric arc)	Resistance of non-permissible machine	Ventilation, testing, permissible machines, rock-dust	36	-	-	-	-	-
68	1924 Mar. 17	Armstrong	Drift, nongassy	15	5	3	Dust	Small	Expansion and lack of dust	Shooting off solid	Blown-out shot	Black powder	Permissible explosives and rock-dust	3	0	0	-	-	-
69	July 25	Fayette	Shaft, gassy	2,300	350	-	Gas and dust	Strong	Active sprinkling	Opened abandoned section unventilated	Electric arc	Fall forced gas out to cable nip	Ventilation, scaling roof, compressed air or storage battery equipment, rock-dust	10	-	-	2	2	51
70	1925 Apr. 26	Westmoreland	Slope, sinking, gassy	0	7	5	Gas	do.	Shaft only	Gas ignored, used flame safety lamps and electric bulbs	do.	Light bulb or wires	Ventilation, permissible electrical equipment	5	0	0	1	1	6
71	Feb. 3	Allegheny	Shaft, gassy	3,700	600	400	Gas and dust	do.	Rock-dust and expansion	Sealing fire from feeder and machine	do.	Open-type machine, no testing	Testing, ventilation, permissible machine	20	0	2	-	-	-
72	1926 June 1	Westmoreland	Drift, gassy	175	55	1	do.	Moderate	Low violence and expansion	Fan stopped off and on, door open	Open light	Fire boss alone in mine	No open lights, proper ventilation	1	0	0	-	-	-
73	Aug. 26	Indiana	Slope, gassy	300	70	52	do.	do.	do.	Interrupted ventilation	Electric arc	Gas moved over broken trolley or blower-fan motor	Split ventilation and rock-dust	44	4	-	3	4	69
74	Mar. 30	Cambria	3 drifts, gassy	1,700	350	294	Dust	6000 ft., strong	Inert dust and expansion	Coupling broke and let 36 cars loose	do.	Power cable, 275 volt, wheel hit splice	Remove cables from haulway, rock-dust	4	-	17	-	-	-
75	1927 Apr. 2	Washington	Shaft, gassy	1,800	350	306	do.	Strong	Rock-dusted entries only	Green man clearing roof fall	blasting	2 mud-capped shots of dynamite	Permissible blasting, thorough rock-dusting	6	5	2	0	0	10
76	Feb. 20	Westmoreland	Shaft, slope, gassy	1,800	500	-	Gas and dust	5000 ft., strong	Dampness and expansion	Fall or open door	Electric arc	Nipping mining machines in return air	Split ventilation, no wires in return, rock-dust	12	-	7	-	-	-
77	Apr. 11	do.	Shaft, gassy	1,100	125	-	do.	Strong	Rock-dust, water, and expansion	Interrupted ventilation	do.	Machine cable	Permissible equipment, water on cutting bar, rock-dust	4	1	-	-	-	-
78	1928 May 19	Greene	do.	3,800	600	270	do.	9000 ft., violent	Little rock-dust, expansion	Open doors	do.	Nonpermissible storage-battery locomotive	Ventilation, permissible equipment, rock-dust	195	-	14	-	-	-
79	Aug. 9	Cambria	Slope, gassy	70	14	10	do.	Small	Low violence and dampness	Machine cut into feeder	do.	Nonpermissible mining machines	Permissible equipment, water, rock-dust	5	0	5	-	-	-
80	Aug. 15	Clearfield	Drift, gassy	550	145	-	do.	Strong	Small volume of water and expansion	Lack of inspection and ventilation	do.	do.	Inspection, ventilation, permissible equipment, rock-dust	13	1	-	1	1	230
81	1929 Mar. 21	Westmoreland	Shaft, slope, gassy	2,000	350	263	Dust	Violent	Partly rock-dusted	Steel conveyor broke in slope (intake)	do.	Cut power cable	Cables out of haulways and rock-dust	46	4	-	1	1	47
82	May 15	Washington	3 shafts, 2 slopes, gassy	1,900	450	-	Gas	Local	Low violence and expansion	Feeder released by pillar fall	do.	Motor or trolley, fire, abandoned	Ventilation, supervision, permissible equipment	3	4	-	-	-	-
83	1930 Aug. 5	Armstrong	Drift, nongassy	350	-	48	do.	do.	Small volume	Poor ventilation	Open light	Lack of inspection	Ventilation, inspection, permissible lights	1	2	-	1	1	5
84	1931 Aug. 28	Clarion	do.	-	2	1	Oil vapor	do.	Volume	Broken oil line near surface	do.	Unexpected occurrence	Provide maps showing pipelines	1	0	0	0	0	1
85	1932 July 29	Somerset	Shaft, mixed lights	2,500	360	60	Gas and dust	do.	Volume and expansion	900 feet ahead of air	Probably conveyor motor (electric arc)	Ventilation, inspection	Ventilation, inspection	3	1	1	0	0	3
	Totals			25,780	19,990	2,540								1,976	137	139	2/ 85	108	1,924

1/ Years marked with an asterisk are those in which there were no major accidents, or in which no accidents occurred.
2/ Ignitions totaled 170: 85 "representative" ignitions and 85 other ignitions.

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Table 7. - Gas and dust explosion fatalities in Pennsylvania bituminous mines, 1879-1931

Period, years	Fatalities per million tons		Percent of explosion fatalities to total killed in Pennsylvania bituminous mines
	Tons	Man-hours	
1879 - 1880	0.17	0.05	5.8
1881 - 1885	.38	.12	12.3
1886 - 1890	.21	.06	7.0
1891 - 1895	.52	.17	15.5
1896 - 1900	.22	.09	6.5
1901 - 1905	.80	.32	18.4
1906 - 1910	.76	.32	18.0
1911 - 1915	.20	.09	6.3
1916 - 1920	.12	.06	4.6
1921 - 1925	.25	.13	9.3
1926 -	.45	.25	16.5
1927	.08	.04	2.8
1928	1.75	.99	44.6
1929	.33	.19	12.3
1930	.04	.03	1.7
1931	.00	.00	0.0
Total 1879-1931	0.335	0.169	12.0

CAUSES OF EXPLOSIONS IN BITUMINOUS MINES

The causes of explosions in bituminous mines are restricted essentially to four: open lights, resulting in 40 explosions; electric arcs, or sparks, resulting in 24 explosions; explosives or blasting devices, initiating 16 explosions; and mine fires, contributing to 4 explosions. Three causes that were listed under explosions in anthracite mines in Pennsylvania do not appear in Table 8. No explosion is known to have been initiated by flame safety lamps in the bituminous mines of Pennsylvania, although 12 explosions were caused by Davy flame safety lamps in anthracite mines. No explosions were attributed to smoking in bituminous mines, although smoking caused 18 explosions in anthracite mines. No explosions in bituminous mines are known to have been caused by furnaces.

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Table 8. - Causes of explosions in Pennsylvania bituminous coal mines, 1878 - 1932

Causes	Number of explosions
Open lights	40
Electric arc or spark	24
Explosives or blasting devices	16
Mine fires	4
Unknown	1
Total	85

Open lights.- Of the 85 explosions listed in Table 6, 40, or 47 percent were caused by open lights. During the 4 years July 1, 1927, to June 30, 1931, open lights caused at least 32.5 percent of all coal mine explosions in the United States; therefore, in Pennsylvania bituminous mines the percentage of explosions by open lights was 14.5 greater than in this 4-year average in the coal mines of the United States, but during this 4-year period, open lights caused only 14.2 percent of the explosions in Pennsylvania mines.

Open lights caused a large percentage of the explosions until 1920, but in the 13 years from 1920 to 1932 there were only 7 explosions from this source. The widespread use of permissible electric cap lamps in Pennsylvania bituminous mines after 1920 undoubtedly is largely responsible for the decrease of explosions from this source.

Electricity.- From 1911 to 1932, inclusive, 24, or 28 percent, of the explosions are charged to electrical ignitions. Since 1924, of 17 explosions listed, 13 or about 77 percent are of this origin. In 1894, a State inspector's annual report included a warning of the increasing hazard from the introduction of electrical equipment into gassy mines. At least in part as a result of special inspection of electrical equipment by the State in 1929 to see that it was maintained in accordance with the standards established by the United States Bureau of Mines, such explosions were reduced to one small ignition in 1930, none in 1931, and one in 1932. This is a real achievement, one of which Pennsylvania bituminous mining men may well be proud and one which could well be studied and followed by coal mining people in other States. The following table gives the types of explosions in Pennsylvania.

Table 9. - Types of explosions in bituminous mines

Condition	Gas	Dust	Gas and dust	Total
Nongassy mines	9	6	7	22
Gassy mines	24	4	35	63
Explosions	~~33~~ 33	10	42	85
Fatalities	189	132	1,555	1,876

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The classification of mines as gassy or nongassy was rather vague until about 1909; from that year until 1924, the nongassy mines figure prominently in the list of mines in which explosions occurred. However, there have been numerous other ignitions resulting in fatal and nonfatal injuries in this class of mine. The United States Bureau of Mines considers all coal mines gassy or potentially gassy and has records of scores of cases in which so-called nongassy mines have almost overnight given off gas in large quantities; in numbers of such cases severe explosions have resulted.

The 85 explosions listed in Table 6 caused 1,876 fatalities; the other 85 unclassified explosions resulted in 108 fatalities. Dust was the largest factor in the fatalities, as the explosions in Pennsylvania bituminous mines in which gas only was involved averaged about 6 killed, even including the most severe gas explosions, while the average number killed where dust or gas and dust were involved was 35.

Blasting and explosives.- One explosion of dynamite in 1888 caused a dust explosion, which was probably the first recognized dust explosion in this country. Blown-out shots and other dangerous blasting risks caused 14 other explosions from 1900 to 1928, most of them prior to 1910 and practically all of them involving dynamite or black blasting powder.

Fires.- Of the 4 ignitions from fires, 1 was from smoldering coals and killed 13 and 3 were from sealed fires opened too soon, costing 27 lives. Mine fires are always a potential cuase of explosions, and when fires occur they should be given the most careful handling.

CAUSES OF GAS ACCUMULATIONS AND DUST SUSPENSIONS IN BITUMINOUS MINES

In 76 explosions gas ignitions were the primary cause and in 9 explosions gas played no appreciable part insofar as can be ascertained, coal-dust alone being the igniting and propagating medium. The largest number of gas accumulations came from insufficient or interrupted ventilation. Open doors ranked second in the cause of gas accumulations, fans and falls of roof or coal were third, and feeders or inrush of gas fourth. Dust was raised into a cloud and ignited by shooting off the solid and other methods of blasting, by cars or conveyors wrecking on slopes, and by a post falling on explosives that in turn detonated. These primary causes of explosions are discussed under the major divisions and are summarized in Table 9.

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Table 9. - Causes of gas accumulations and dust suspensions in Pennsylvania bituminous mines

Causes	Explosions
Insufficient or interrupted ventilation	33
Insufficient ventilation at face	11
Insufficient ventilation, other than at face	7
No ventilation	6
Interrupted ventilation	2
Gas found but not removed	2
Careless ventilating practice	1
Gas in cavity at face	1
Raised curtain, hole in pillar	1
Water flooded section cut off air in shaft	1
Repairing stopping	1
Open doors	16
Door left open	14
Door removed	1
Cars left in door	1
Fans	10
Fan idle; moved gas when started	7
Fan not operating	3
Falls of roof or coal	10
Fall of roof released gas	4
Pillar removal and falls	2
Fall broke gas or oil pipe line om surface	2
Squeeze caused short-circuit of air	1
Fall of roof or open door	1
Feeders and inrush of gas	6
Feeders opened by pillar removal	2
Feeders released by cutting coal	2
Gas rushed in from abandoned mine	1
Feeder from floor	1
Miscellaneous	3
Removing fire seals before fire extinguished	3
Gas released by blasting	1
Dust raised into suspension	9
Shooting off solid	3
Blasting	3
Trip of cars wrecked on slope	1
Broken conveyor on slope	1
Post fell on explosives	2

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Insufficient or interrupted ventilation.- Of the 85 explosions listed in Table 6, 33 were caused by ignition of gas that accumulated through insufficient or interrupted ventilation. Insufficient ventilation at the face resulted in 11 accumulations, and 7 accumulations resulted from insufficient ventilation in places other than the face. "No ventilation" allowed gas to accumulate prior to 6 explosions. Interrupted ventilation and gas found but not removed were each responsible for 2 gas accumulations. Other causes were the result of careless ventilating practices, gas in cavity in roof not removed, a curtain raised or a hole in a pillar short-circuiting the air, water cutting off air in a shaft, and failure to provide temporary brattice while repairing a stopping.

Open doors.- In 14 explosions, gas that was ignited had previously accumulated through doors being left open. The removal of a door and cars left in a door each were responsible for gas accumulations.

Fans.- Fans should be operated at all times, and failure to do so may result in gas accumulations; saving money by shutting down the fan on idle days is likely to prove expensive economy in the long run. Shutting down fans in 7 instances allowed gas to accumulate; explosions followed, in each instance when the gas was moved over a source of ignition when the fans were started. In 3 cases gas accumulated while fans were not operating.

Feeders or inrush of gas.- Sudden inrushes of gas occur when feeders are released when coal is cut, or when pillars are removed, or when falls occur. Falls or removal of barrier pillars may release gas in an adjoining abandoned mine and force it into the working property. Feeders were released and ignited in 6 cases, as recorded in Table 6; the best protection against occurrences of this type is the elimination of sources of ignition such as open lights, nonpermissible electrical equipment, etc.

Other causes.- In 3 explosions, gas that had accumulated when fires were sealed was diluted to form explosive mixtures and was ignited by smoldering fires when seals were removed before the fires were extinguished. Blasting released gas and ignited it in at least one instance.

Dust raised into suspension.- Nine of the explosions were classed wholly as dust explosions and 7 of these were caused by blasting or explosives. In 3 explosions dust was raised into a cloud and ignited by explosives where coal was shot off the solid. Blasting caused combustible dust to be raised into the air and ignited by the explosives in 3 instances, 1 when blasting rock for an overcast, 1 when coal was blasted without stemming being placed in the shot hole, and 1 when mud-capped shots were fired.

A trip of cars wrecked on a slope threw dust into suspension, and an arc from the trolley wire ignited the dust. The breaking of a coal conveyor threw into suspension a dense cloud of coal-dust and which was ignited by an electric arc.

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PREVENTION OF EXPLOSIONS IN PENNSYLVANIA BITUMINOUS MINES

The recommendations for preventing a recurrence of similar explosions were made in reports of the various explosions. These represent, in general, the accepted safety practices at the time they were made, and as such are of interest. The recommendations and the number of times each was made are given in Table 10.

Table 10. - Recommendations for preventing explosions at time of explosions in bituminous mines of Pennsylvania

Recommendations	Times made
Ventilation	44
Inspection	33
Dust control (watering, rock-dusting, water on cutter bar)	31
Permissible (closed) lights	22
Flame safety lamps	15
Permissible explosives and blasting devices	15
Permissible or storage-battery equipment	12
Supervision	6
Testing for gas by machinemen	3
Inspection of idle workings	2
Care with fires	2
Removal of gas	2
Maps of and care with surface gas and oil lines	2
Remove cables from haulage road	2
Care in approaching old workings	1
Keep detonators and explosives apart	1
Leave fires sealed until they are extinguished	1
Seal old workings	1
Leave sufficient pillars around fire area	1
Auxiliary fan	1
Restrict extension of wiring	1
Cut off power in idle sections or idle mine	1
Proper stoppings	1
Scaling roof	1
No electric wires in return airways	1

Ventilation.- The need for well-designed systems of ventilation is of even greater importance in bituminous mines than in anthracite mines, for an ignition of gas that may cause little damage and no injuries in anthracite mines may develop into a widespread explosion in bituminous mines through propagation by explosive coal-dust. This hazard and the need for taking precautions is reflected in the 44 times that recommendation for improving ventilation was made.

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Fans adequate for the needs should be provided and the air should then be taken to the working faces with a minimum of loss. Some of the best-ventilated Pennsylvania mines conduct at least 90 per cent of the air to the working areas. This is accomplished by constructing tight, fireproof stoppings, providing large area openings for conducting air--generally accomplished by utilizing a number of entries for airways--by eliminating doors wherever possible through construction of overcasts, and by sinking auxiliary shafts or extending entries to the outcrops as the workings advance to provide fresh air near the active workings and simultaneously to reduce the amount of travel of the air with attendant decrease in power consumption by the fan.

Inspection.- The second largest number of recommendations, 33, was for improving methods of inspection, generally interpreted to mean that testing for gas should be more thorough and that closer attention should be given to the ventilating system to prevent gas from accumulating. While these are two of the important duties of an inspector or supervising official, it is equally important that he should maintain a constant survey of dust-control methods such as watering and rock-dusting, keep a close check on electrical equipment to see that the possibility of producing an external spark or arc is reduced to a minimum, and see that open-flame lamps are not used, smoking is not allowed, and that open-type equipment, if impracticable to prohibit underground, is restricted to use in strictly fresh air.

Dust control.- The control of dust by rock-dusting and watering was recommended 31 times, indicating that the hazard of dust in bituminous mines was recognized by the trained investigators, but that the mine operators disregarded or were unaware of the extreme hazard of combustible dust. Explosions may be controlled if rock-dust is applied in amounts large enough to render the combustible dust inert to explosibility and if all open parts of the mine are rock-dusted to within at least 50 feet of every active working place and to the face of every idle or abandoned unsealed place. Watering should be practiced to allay the dust at the source; water should be applied on the cutter bar of mining machines during cutting, and the face region should be wetted before blasting, the coal pile should be kept wet during loading, and the tops of loaded cars should be wetted before the cars are hauled from the working place. Water should also be sprayed on loaded trips before leaving a section, and considerable success has been attained by sprinkling haulage-road beds as an adjunct to rock-dusting.

Rock-dusting has been advocated by various engineers both in and out of the Bureau of Mines in the United States from 1908 onward. About 1913 it was generally proposed by the Bureau of Mines engineers as a preventive measure, and in 1923 it was made an official recommendation of the Bureau of Mines, based on long series of tests in its Experimental mine, though it was used but little in commercial mines until after that date. In the last few years there have been numerous cases where serious disasters have been averted in mines so protected, and there must have been many more which have gone unrecorded and perhaps unnoticed. (See Bureau of Mines Inf. Circ. 6596, April, 1932.)

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Permissible (closed) lights.- The fourth largest number of recommendations (22) was that permissible (closed) lights be used for miners' portable lighting. The danger of open lights has generally been recognized and most of the mine workers in Pennsylvania bituminous regions are provided with permissible electric cap lamps; nevertheless, large numbers of open lights are now being used, and in any mine whether gassy or so-called nongassy they will always be a source of ignition of dust, explosives, and possibly of gas.

The installation of closed lights, however, in many cases results in neglect of ventilation. This should never be allowed, as such neglect is very likely to result in explosions of gas ignited by electric arcs or smoking.

Flame safety lamps.- Under "Inspection" it was pointed out that testing for dangerous mixtures of gas and air is essential to prevent the accumulation of gas unknown to workmen in the mine. At present the flame safety lamp is one of the quickest instruments for determining the presence of gas and at the same time indicating oxygen deficiency. It is doubtful if the average person making tests for gas detects less than 3 per cent of methane, although by "capping" the flame, careful inspectors who have very good eyesight may detect less than 1 percent. The flame safety lamp is safe only when properly assembled and in the hands of a competent, carefully trained person. All flame safety lamps should be tested in a scientifically designed testing box; reliance should not be placed on time-honored but inefficient methods of testing flame safety lamps by blowing on or at them. All lamps should be permissible, magnetically-locked types, and those locks should not be tampered with.

Safety lamps and closed lights.- Electric cap lamps in use in the bituminous mines of Pennsylvania have increased from a number estimated to be 800 in 1913 to 106,640 in 1932. The rapid adoption of closed lights was undoubtedly responsible for the marked decrease in open-light explosions after 1920. The United States Bureau of Mines started testing electric lamps in 1909, and granted the first approval in 1913. The State inspectors were constantly striving for better ventilation and inspection since first appointed in 1877. They obtained cooperation of the operators to an extent that was responsible for rapid and continued improvements. The new code, put into effect in 1911, called for locked flame safety lamps approved by the United States Bureau of Mines, and permissible explosives when ordered by the inspectors.

Permissible explosives and blasting devices.- The hazards of black powder and dynamite are generally well known, and the effectiveness and safety of permissible explosives are generally recognized; nevertheless, nonpermissible explosives are still widely used and even where permissible explosives are used, black powder and long-flame dynamite are also used. The hazard of using mixed explosives is often greater than the use of nonpermissible explosives alone.

Electrical blasting is by far safer than is blasting by fuse or squibs though electrical blasting itself is by no means foolproof. Electrical

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blasting devices should be of a permissible type, for tests have shown repeatedly that multiple and nonpermissible blasting devices will ignite gas. Unquestionably one means of preventing explosions in both dusty and gassy bituminous coal mines is to use permissible explosives in a permissible manner, and to blast with permissible blasting units.

Permissible explosives.- The types and quantity of explosives used in Pennsylvania bituminous mines follow:

Classes of explosives used in bituminous mines

Year	Black powder	Dynamite	Permissible
1901	7,900,000	1/ 676,000	- - -
1917	19,071,275	2,332,339	8,218,750
1931	5,935,525	965,045	8,067,007

1/ According to State Mine Inspector's report.

The Rolling Mill explosion in 1902 fixed attention on the need of safer types of explosives; some early types were developed at this time and were widely used after the Harwick disaster in 1904. Through establishment of the United States ~~Bureau of Mines~~ Experiment Station testing station in ~~1909~~ 1910 at Pittsburgh, new and improved brands of explosives were placed on the market. Modern blasting devices are not foolproof, but by observance of known and proved limitations in their use, ignitions from this source can be prevented. However, there are several pertinent points still to be studied in firing practice and the development of blasting units, but unquestionably the best method of preventing widespread explosions with heavy loss of life through blasting in bituminous coal mines is to do all blasting work when the working shift is out of the mine.

Permissible storage-battery or other permissible equipment.- Twelve recommendations were made for the use of permissible equipment, including storage-battery equipment. The use of electrical equipment underground introduces numerous sources of gas and dust ignition. During the four years ended June 30, 1931, Bureau of Mines Information Circular 6540 shows that 45.8 percent of the mine explosions in the United States were of electrical origin and that the fatalities resulting from the explosions of electrical origin constituted 74.8 percent of all explosion fatalities. In other words, if electrical equipment had been permissible and maintained in a permissible condition, nearly three fourths of the explosion fatalities might have been prevented, as there is not on record an explosion known to have been initiated by permissible electrical equipment.

For mine use, permissible mining machines, rock-dusting machines, pump motors, telephones, junction boxes, switches, locomotives, lights and practically every type of electrical equipment needed in mines are available. Their use and proper maintenance will help to prevent explosions. The record

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shows that nearly 77 percent of the explosions in the bituminous mines of Pennsylvania since 1924 have been initiated by electric arcs from nonpermissible electrical installations, and it is to be hoped that the vigilance of the past 3 years as to electrical equipment in Pennsylvania bituminous mines will not be relaxed.

Supervision.- The eighth recommendation, made only 6 times, is for adequate supervision. Unquestionably this recommendation could well have been made in numerous other cases. It is through supervision that ventilation is effectively maintained, inspection is kept efficient, dust is controlled, and adequate safeguards as to igniting agencies are provided; it is the backbone of explosion prevention, just as it is the keystone of the provention of accidents of all kinds and of efficient operation as well.

Miscellaneous recommendations.- Seventeen other recommendations are made, but each is a corollary to the main recommendations.

Fatalities and mine explosions.- A study of production and of data on the number killed in gas and dust explosions in bituminous mines of Pennsylvania from 1878 to 1932 indicates that there is essentially no correlation between production and fatalities or explosions. Naturally, where mines have been closed for considerable periods by strikes, the number of explosions drops. The small number of explosions in relation to the high cost in lives is clearly shown. The high peaks from great disasters are regularly followed by low points, showing that renewed precautions and preventive measures induced by such lessons are effective, until forgetfulness and slackness leaves another opening, or in some cases a new and unforeseen combination of agencies arises.

Table 11. - Number of explosions and fatalities from explosions in Pennsylvania mines, 1847 - 1932

Years	Anthracite mines		Bituminous mines	
	Number of explosions	Fatalities	Number of explosions	Fatalities
- 1869	1/ 4	1/ 13		
1870 - 1879	119	269	1/ 3	1/ 5
1880 - 1889	109	223	23	84
1890 - 1899	191	409	23	177
1900 - 1909	221	355	53	909
1910 - 1919	261	424	28	255
1920 - 1929	291	450	35	545
1930 - 1932	2/ 36	2/ 70	2/ 5	2/ 9
Totals	1232	2213	170	1984

1/ Two years only recorded.
2/ Three-year period.

Some essential facts on explosions and the fatalities from explosions in Pennsylvania coal mines have been arranged by decades from 1870 to 1932 in

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Table 11. In the anthracite mines from 1890 to 1929, inclusive, the number of explosions increased at the rate of about 3 per cent; however, in the 3-year period 1930 to 1932, inclusive, there were only 36 explosions; at the rate of 120 in 10 years, this is a notable decrease from the 291 which occurred in the decade 1920 to 1929, inclusive. The fatalities ranged from 355 to 450 each decade from 1890 to 1929, or 35 to 45 per year; in the years 1930 to 1932, inclusive, the fatalities have been at the rate of about 23 per year, a definite improvement on the past but by no means an irreducible minimum of fatalities from explosions in anthracite mines.

In the bituminous mines from 1880 to 1929 there have been 23 to 53 explosions per 10 years, with fatalities ranging from 84 to 909. During the 3 years 1930 to 1932, inclusive, in 5 explosions 9 men were killed, an admirable record and one difficult to improve. The average number of explosions per year in the last 3-year period was at a rate about half that of the other periods, and the number killed was from one third to one tenth of the average for preceding periods.

The United States Bureau of Mines, through its Mine Safety Board, issues "decisions" on safety methods and practices. Such decisions as relate to explosion prevention methods are as follows:

Decision 1:

The Bureau of Mines recommends:

(a) In all coal mines the portable lamps for illumination be permissible, portable, electric mine lamps; and also

(b) In places where fire damp or black damp is liable to be encountered, a permissible magnetically-locked flame safety lamp for gas detection, or equivalent permissible device, be supplied to at least one experienced employee in each such place; and

(c) Any employee before being supplied with a permissible flame safety lamp be examined by a competent official of the mine to assure the man's ability to detect gas; and

(d) All coal mines whether classed as nongassy or gassy in any part, be supplied with magnetically locked, permissible, flame safety lamps, properly maintained and in sufficient number for all inspection purposes.

Decision 2:

In the interests of safety the Bureau of Mines recommends that for blasting in coal mines, permissible explosives, fired electrically, be exclusively used; and that as an aid to blasting, all coal which is feasible to cut, should be cut or sheared.

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Decision 4:

In the interest of safety, the Bureau of Mines, Department of Commerce, recommends that auxiliary fans or blowers should not be used in coal mines as a substitute for methods of regular and continuous coursing of the air to every face of the mine.

Decision 5:

To prevent the propagation of mine explosion, the Bureau of Mines, Department of Commerce, recommends rock-dusting all coal mines, except anthracite mines, in every part, whether in damp or dry condition. It also recommends that rock-dust barriers be used to sectionalize the mine as additional defense; but these should not be regarded as a substitute for generalized rock-dusting.

Decision 6:

In the interest of safety, the Bureau of Mines, Department of Commerce, recommends that in coal mines all entries, rooms, panels, or sections that cannot be kept well ventilated throughout or cannot be inspected regularly and thoroughly, or that are not being used for coursing the air, travel, haulage, or the extraction of coal, be sealed by strong fireproof stoppings.

Decision 7:

In the interest of safety, the Bureau of Mines, Department of Commerce, recommends:

1. That the main intake and main return air currents in mines be in separate shafts, slopes, or drifts.

2. That the main intake shaft lining be of fireproof construction, and there be a minimum amount of inflammable material in or adjacent to the shaft.

Decision 9:

The Bureau of Mines, Department of Commerce, recommends in coal-mine ventilation practice the following specifications as to unit quantity and quality of air:

1. The quantity in cubic feet of pure intake air flowing per minute in any ventilating split shall be at least equal to 100 times the number of men in that split.

2. The quantity of air entering each unsealed place shall be at least 200 cubic feet per minute and as much more as may be necessary to properly dilute, and carry away inflammable or harmful gases which may be present.

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3. The air shall be made to circulate continuously to the face in every unsealed place into which an appreciable amount of methane enters.

4. The air in any unsealed place shall be considered unfit for men if it shall be found to contain less than 19 percent oxygen (dry basis), more than 1 percent carbon dioxide, or a harmful amount of poisonous gas.

5. If the air in any unsealed place, when sampled or tested in any part of that place not nearer than 4 feet from the face and 10 inches from the roof, shall be found to contain:

(a) more than 1-1/2 percent of inflammable gas, the place shall be considered to be in hazardous condition and require improved ventilation, and

(b) if more than 2-1/2 percent of inflammable gas is found, the place shall be considered dangerous, and only men who have been officially designated to improve the ventilation and are properly protected shall remain in or enter said place.

6. If the air in the split which ventilates any group of workings contains more than 1-1/2 percent of inflammable gas, these workings shall be considered to be in a dangerous condition and only men who have been officially designated to improve the ventilation and are properly protected, shall remain in or enter said workings.

ecision 11:

In the interest of safety, the Bureau of Mines, Department of Commerce, recommends that in coal mines, haulage and (or) hoisting be kept in intake air as far as possible.

ecision 12:

The Bureau of Mines, Department of Commerce, extending Mine Safety Decision No. 2, recommends that for blasting either coal or rock in coal mines, permissible explosives or equivalent permissible device be used exclusively, and in addition recommends that in blasting

1. Each charge shall be in a hole properly drilled and stemmed with incombustible material.

2. Each shot shall be fired separately by a permissible single-shot blasting unit, using an electric detonator or igniting equivalent of a kind specified by the bureau for the particular permissible explosive or permissible blasting device.

02

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3. Before and following each shot in gassy and slightly gassy coal mines, examination for gas shall be made with a permissible flame safety lamp or permissible equivalent and

4. If more than 1-1/2 percent of inflammable gas is found, in the quantity and by the method specified in Mine Safety Decision No. 9, the place shall be considerod to be in a hazardous condition and before another shot is fired the gas shall be reduced by ventilation below the percentage and quantity specified in Decision No. 9.

5. Each shot employing explosives shall be prepared and fired by or under the immediate supervision of a man having a state certificate as a mine examiner, fire boss, or foreman, and whenever conditions permit all other men than those authorized to prepare and fire shots shall be out of the mine when shot firing with explosives is being done.

Decision 13:

The Bureau of Mines, Department of Commerce, recommends that when electricity is used in coal mines rated as gassy, or wherever in any mine the atmosphere may become gassy:

1. Electrical equipment shall be permissible.

2. Nonpermissible electrical equipment shall be used only in pure intake air.

3. Electrical power shall be cut off whenever the air in the workings is in a dangerous condition, due to inflammable gas.

Decision 15:

In the interest of safety in coal mining, the Bureau of Mines, Department of Commerce, recommends that, to lessen the coal-dust explosion hazard:

(a) Machine coal cuttings be wet as the cutting is being done.

(b) The coal face, and the working place 40 feet therefrom, shall be kept free of coal-dust by the use of water.

(c) The top of loaded cars in the working place shall be wet.

Decision 16:

In the interest of safety in coal mining, the Bureau of Mines, Department of Commerce, recommends that:

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(a) Machine cuttings be removed from the cut.

(b) If the machine cuttings are of a character which would contribute to a dust explosion, they shall be sent out of the mine.

ision 17:

To lessen the formation and distribution of coal dust in haulage ways, the Bureau of Mines, Department of Commerce, recommends that in bituminous and lignite coal mines:

(1) The mine cars should be constructed and maintained dust-tight.

(2) The coal should be so loaded that it will not shake off in haulage.

(3) The cars and loads should be so sprayed as to prevent dust being distributed along the haulage ways.

ision 18:

In the interest of safety in coal mining, the United States Bureau of Mines recommends that:

(1) The foreman regularly in charge of underground operations and also any person who, in the absence of the foreman, may be placed in temporary charge should each have a certificate of competency from the State to act as mine foreman.

(2) The superintendent or person in responsible charge of the mine, to whom the mine foreman reports, should have a certificate of competency from the State which should be issued upon a showing of underground experience for a period of time as long as that required for a foreman's certificate and upon passing an examination including all technical questions asked in the examination required of foremen.

(3) These certificates should expire after some stated period of time, such as 5 years, and should be removed only after the applicant has again passed the examination required by the State.

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Decision 20:

In the interest of safety in underground mining, the United States Bureau of Mines recommends that while driving tunnels or drifts and sinking or raising shafts or slopes, and also in their operation, there should be an adequate ventilating current wherever men work or travel.

CONCLUSIONS

The very good record made in reducing the number and the accident severity of explosions during the last 3 years in Pennsylvania coal mines is largely due to greater effort on the part of State mine inspectors and the closer supervision given by the inspectors. Many mines are idle, and hence the inspectors are able to visit the operating mines more frequently and thus maintain a closer supervision. Credit for the reduction in explosions also is due the mine operators and mine workers who, in spite of unfavorable economic conditions, have in general given closer attention to safety, and to educational work looking to the forwarding of safety.

The principal primary causes of explosions have been insufficient or interrupted ventilation, open ventilating doors, release of gas by squeezes, falls or runs of roof or coal, the use or rather misuse of auxiliary fans underground, intermittent operation of fans, use of nonpermissible explosives and blasting units, release of feeders or bodies of gas by blasting or cutting into gassy beds or abandoned workings, and, in bituminous mines, dust thrown into suspension by blasting or by wrecked trips and conveyors. The chief causes of ignition of gas or dust were open lights, explosives or blasting devices, electric arcs or sparks, smoking, defective or carelessly handled flame safety lamps, and mine fires.

Explosion prevention depends primarily upon effective supervision, adequate ventilation, the exclusive use of permissible electric cap lamps for portable lights, the use of magnetically locked, flame safety lamps for testing for gas and for light, blasting with permissible explosives and permissible blasting units, and the use of permissible-type electric equipment. These fundamentals become effective when the underground employees are instructed in them, and such instruction is best accomplished by maintaining an active safety organization.

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